

## WINTER HABITAT OF COMMON LOONS ON THE CONTINENTAL SHELF OF THE SOUTHEASTERN UNITED STATES

J. CHRISTOPHER HANEY<sup>1</sup>

**ABSTRACT.**—Population size, habitat use, and habitat selection of wintering Common Loons (*Gavia immer*) were studied on the southeastern U.S. continental shelf. Winter population estimates ranged from 8700 to 20,000 individuals for the shelf between 29° and 35°N latitude. Loons used shelf waters up to 100 m in depth and 100 km from land. Significant differences in habitat use and selection were found among four shelf habitats differentiated by water depth, distance from land, and water mass properties. Loons selected for waters 0–19 m deep but avoided highly turbid waters within 5–15 km of shore. Loon distribution shifted farther offshore during midwinter, as the areal extent of turbid water increased near shore due to seasonal peaks in river discharge. *Received 21 Oct. 1988; accepted 5 Nov. 1989.*

Considerable concern has been expressed over the population status of the Common Loon (*Gavia immer*). Potential impacts on loons during the nesting season include human disturbance at breeding lakes, acid rain alteration of lake ecosystems, and mercury poisoning of adults (Ream 1976, Titus and Van Druff 1981, Haseltine et al. 1983, Alvo 1986, McIntyre 1986). Die-offs of loons correlated with mercury intoxication have occurred during winter along both the Gulf and Atlantic coasts of the southeastern United States (Alexander 1985).

Very little is presently known about the winter distribution and ecology of Common Loons. Although use of marine waters is well-documented, there are conflicting accounts of whether and to what extent loons use deep, offshore waters on continental shelves (cf. Bent 1919, Cramp and Simmons 1974, Lee 1987). The few dedicated studies of wintering loons have been conducted in sounds and along beach fronts (e.g., McIntyre 1978, Daub 1989). The objectives of this study were to: (1) provide population estimates of wintering Common Loons for the South Atlantic Bight, that area lying between Cape Hatteras, North Carolina, and Cape Canaveral, Florida, and (2) describe marine habitat use and selection by loons within this region. Marine habitat selection was examined as a function of water depth and clarity, environmental variables of potential importance to these visually oriented, diurnal predators (McIntyre and Barr 1983).

<sup>1</sup> Dept. Zoology, Univ. Georgia, Athens, Georgia 30602. (Current address: Center for Marine Policy and Ocean Management, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543.)

TABLE 1  
COMMON LOON USE OF OFFSHORE HABITATS DEFINED BY DEPTH ON THE SOUTHEASTERN  
U.S. CONTINENTAL SHELF

Habitat	Proportion of survey effort ( $p_{io}$ )	Number of loon observations	Expected number of loon observations	Proportion observed in each habitat ( $p_i$ )	Confidence interval on proportion of occurrence (95% family confidence coefficient)
0–19 m	0.363	55	32	0.625	$0.495 < p_1 < 0.754$
20–39 m	0.269	25	24	0.284	$0.164 < p_2 < 0.404$
40–59 m	0.278	7	24	0.080	$0.008 < p_3 < 0.152$
60–200 m	0.090	1	8	0.011	$0.000 < p_4 < 0.039$
Total	1.000	88	88	1.000	

#### STUDY AREA AND METHODS

The marine zone between Cape Hatteras, North Carolina, and Cape Canaveral, Florida, is characterized by: (1) the proximity of the Gulf Stream to shelf water masses, (2) a wide (80–160 km) and shallow continental shelf uninterrupted by ledges, banks, or submarine canyons, and (3) the absence of a typical continental slope (Atkinson et al. 1983). Four water masses with different physical and biological properties exist on or near the continental shelf. These water masses are subdivided by depth zones at the 0–20 m (inner shelf), 21–40 m (middle shelf), 41–60 m (outer shelf), and 61–200 m (shelf break) isobaths. Within the inner shelf water mass, a boundary or front (Bowman and Esaas 1978) separates highly turbid water (emanating from coastal estuaries and rivers) from clearer water offshore. The position of the front and the areal extent of turbid water varies with seasonal changes in river discharge rates (Atkinson et al. 1983).

Observations of Common Loons were made during 159 days of seabird surveys in the South Atlantic Bight between May 1982 and June 1985. Survey tracks were mostly opportunistic but frequently repeated among the 43 cruises conducted. All observations were made between 29° and 35°N latitude, primarily on the continental shelf (0–200 m depths). A total of 2476 km<sup>2</sup> was censused using 2118 300-m band transect, 15-min counts (Haney 1986). A fixed-interval rangefinder was used to compute the transect boundary (Heinemann 1981). This method permitted expressing the numbers of loons either as a function of surface area censused or per count hour. Seasonal breakdown of the 15-min counts was as follows: June–August, 664; September–November, 558; December–February, 232; March–May, 664.

Date, latitude and longitude, heading of ship, time of day, visibility, sea height, wind speed and direction, depth, and sea surface temperature were recorded for each count transect. Behavior and, if applicable, feeding associations of loons were also noted during counts and when ships were on station. Loon densities were plotted as a function of depth and distance offshore for all cruises and observations. Seasonal changes in the cross-shelf distribution of loons were plotted in relation to monthly variations in river discharge rates.

Selection and use of marine habitats by loons were examined first by categorizing each loon observation into one of the depth zones described above, using the ship-board LORAN-determined position of the transect. Transects were stratified by habitat categories corresponding to the four principal environmental divisions in the study area (Atkinson et al. 1983) prior to statistical testing. This was done in order to improve inferences about relationships between observational data and environmental measurements (James and Mc-

TABLE 2  
COMMON LOON SELECTION OF OFFSHORE HABITATS DEFINED BY DEPTH ON THE  
SOUTHEASTERN U.S. CONTINENTAL SHELF

Habitat	Proportion of total study area available ( $p_{i0}$ )	Adjusted number of loon observations <sup>a</sup>	Expected number of loon observations	Proportion observed in each habitat ( $p_i$ )	Confidence interval on proportion of occurrence (95% family confidence coefficient)
0–19 m	0.336	38	23	0.543	$0.394 < p_1 < 0.692$
20–39 m	0.455	23	32	0.329	$0.189 < p_2 < 0.469$
40–59 m	0.142	6	10	0.086	$0.002 < p_3 < 0.170$
60–200 m	0.067	3	5	0.042	$0.000 < p_4 < 0.102$
Total	1.000	70	70	1.000	

<sup>a</sup> Numbers (Table 1) were adjusted by a scaling factor ( $p_{i0}/0.25$ ) to account for differences in census effort among habitat types.

Culloch 1985). Each statistical unit consisted of one or more individual loons observed sitting on the water surface within a transect. Transect length and surface area averaged approximately 4.4 km and 1.4 km<sup>2</sup>, respectively. Because these dimensions are considerably larger than individual winter feeding territories of 4–8 ha recorded by McIntyre (1978), transects provided robust and conservative units for subsequent analyses of habitat use and selection.

The proportion of survey effort during fall, winter, and spring months (Nov–Apr) allocated to each habitat (Table 1) was used to test the following hypothesis with the chi-square technique: loon use across all habitats was equal, and thus abundance was in proportion to survey effort. In order to meet the assumptions for calculating a test statistic that was approximately chi-square distributed, the number of habitat categories was chosen so that: (1) there was at least one expected observation in each category, and (2) no more than 20% of all categories contained less than five expected observations (Dixon and Massey 1969: 238). In practice, no categories contained less than eight expected observations for this test.

In a similar fashion, the chi-square test statistic was used to examine habitat selection across all habitat types, i.e., preference or avoidance of habitats with respect to availability. Expected values for this test were determined by calculating the proportion of the total surface area taken by each habitat in the study area (Table 2). Because of differences in survey effort across habitats, the numbers of loon observations were first adjusted by a scaling factor which resulted in fewer total observations (70 vs 88 in the first test; Table 2), but this again provided a robust and conservative test. No categories contained less than five expected observations for the test.

Both chi-square tests considered all habitats simultaneously. To test for use and selection for each individual habitat, the Bonferroni  $z$ -statistic was employed (Neu et al. 1974, Byers et al. 1984, Alldredge and Ratti 1986). A set of simultaneous confidence intervals was constructed for the true (observed) proportion of use ( $p_i$ ) of each of the four habitats in each test. Where the expected proportion of usage ( $p_{i0}$ ) does not lie within this interval, differences between expected and observed use of individual habitats can be identified as significantly different.

Prior to population estimates, distributions of loon counts were tested for normality, skewness, and kurtosis. Populations of Common Loons were estimated by two methods. First, the total numbers of sitting loons were divided by the total surface areas censused for

each habitat. Second, the mean number of loons  $\text{km}^{-2}$  was computed for each habitat using the total number of transects (including zero count transects) for that habitat. A 90% confidence interval (C.I.) was then figured using standard methods (Bhattacharyya and Johnson 1977). Total numbers of Common Loons for the South Atlantic Bight continental shelf between 29° and 35°N latitude were calculated using mean values and their confidence intervals extrapolated to the total surface area available in each habitat as given in Atkinson et al. (1983).

## RESULTS

The chi-square test revealed that use across all four shelf habitats by Common Loons was not equal, i.e., in proportion to sampling allocation ( $\chi^2 = 30.98$ ,  $P < 0.005$ ,  $df = 3$ ). Loons used the 0–19 m habitat in greater proportion than expected, the 20–34 m habitat within the expected range of probability, and both the 40–59 and 60–200 m habitats in lower proportions than expected by chance (Bonferroni  $z$ -statistics; Table 1). Similarly, loons selected habitats disproportionately to availability as defined by areal extent ( $\chi^2 = 14.71$ ,  $P < 0.005$ ,  $df = 3$ ). Loons selected the 0–19 m habitat in greater proportion than expected; however, the three remaining shelf habitats were selected in approximate proportion to their availability (Bonferroni  $z$ -statistics; Table 2).

Loon abundances also varied across the continental shelf on a finer scale (Fig. 1). Abundances ranged from 1.0 to 3.4 birds  $\text{km}^{-2}$  within about 5 to 90 km offshore. Very few loons were observed beyond 100 km or in waters deeper than 20 m. A very pronounced decline in offshore abundance occurred near the beginning of the shelf break.

Loons were either rare or absent within a 5–15 km band of turbid water near shore (Fig. 2). The Landsat infrared photograph reveals sediment-laden water emanating from coastal estuaries and Georgia rivers such as the Savannah, Ogeechee, Altamaha, and St. Mary's. Annual discharge of river water varies seasonally, with greater volumes and cross-shelf transport of turbid water during winter and spring. Mean distances from shore and near shore limits occupied by loons retreated farther offshore during these months (Fig. 3).

Count frequencies of loons were not distributed normally in any of the four habitats. Frequency distributions exhibited very high degrees of both kurtosis and positive skewness, a not uncommon trait in at-sea counts of marine birds (Schneider and Duffy 1985). Approximations for computing C.I.'s from non-normal distributions can be made, however, if sample sizes are large (e.g., the inner and middle shelf habitats) (cf. Table 3; Bhattacharyya and Johnson 1977:244).

Population estimates (Table 3) calculated by the total-area-censused method were 13,692 for the inner shelf (0–19 m), 4370 for the middle shelf (20–39 m), 0 for the outer shelf (40–59 m), and 286 for the shelf

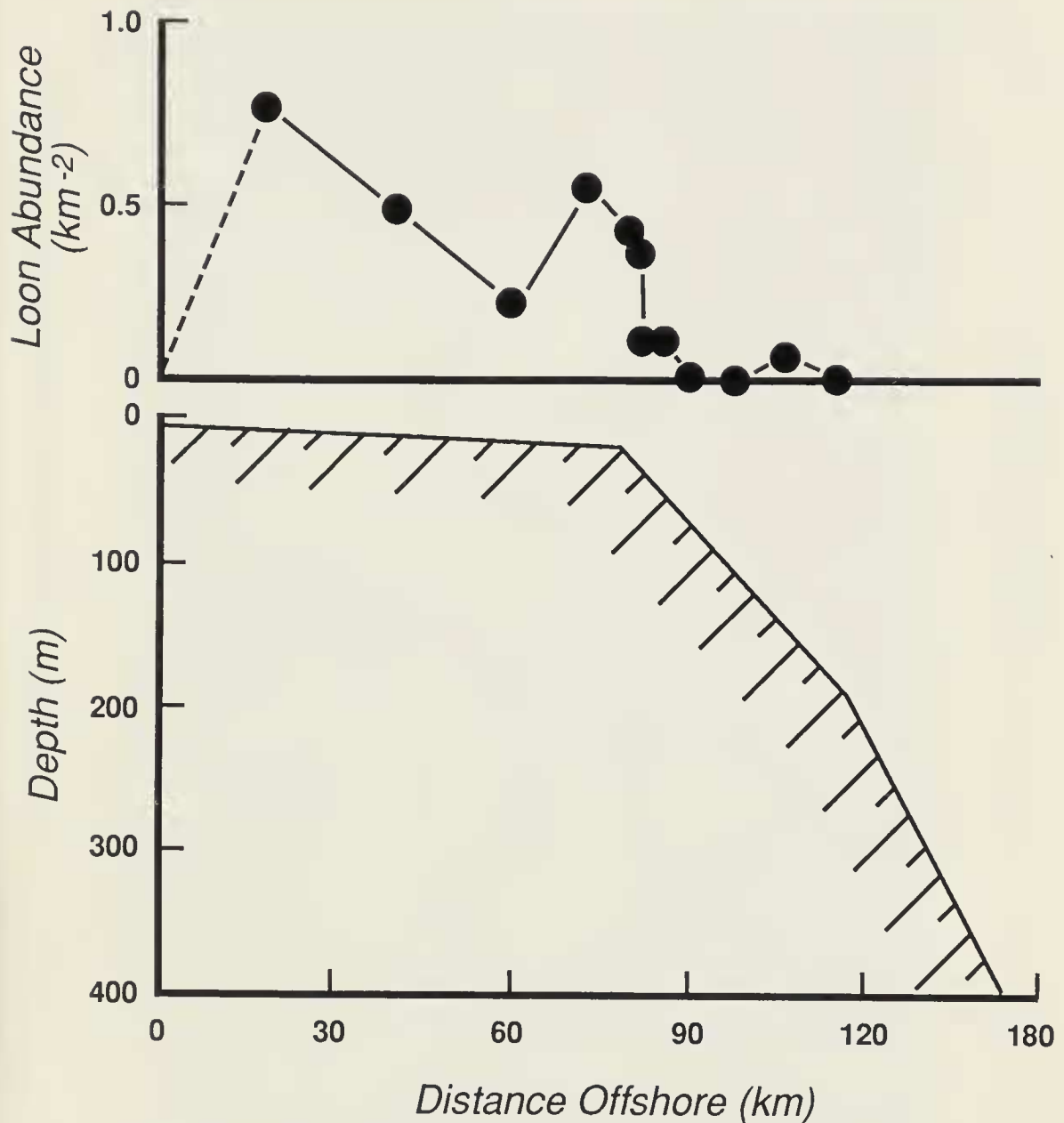


FIG. 1. Cross-shelf abundances of Common Loons off the coast of the southeastern United States. Data points represent mean abundances of loons within twelve ocean depth ranges: 0–5, 6–7, 8–9, 10–11, 12–13, 14–17, 18–20, 21–26, 27–48, 49–69, 70–91, and 92–115 m.

break (60–200 m). Numbers using the mean and 90% C.I. for each habitat were:  $10,675 \pm 2745$  on the inner shelf;  $3304 \pm 2478$  on the middle shelf; 0 for the outer shelf; and  $286 \pm 429$  on the shelf break. Regional estimates for Common Loons on the continental shelf between  $29^{\circ}$  and  $35^{\circ}\text{N}$  thus ranged from an approximate minimum of 8700 to a maximum of 20,000 individuals.

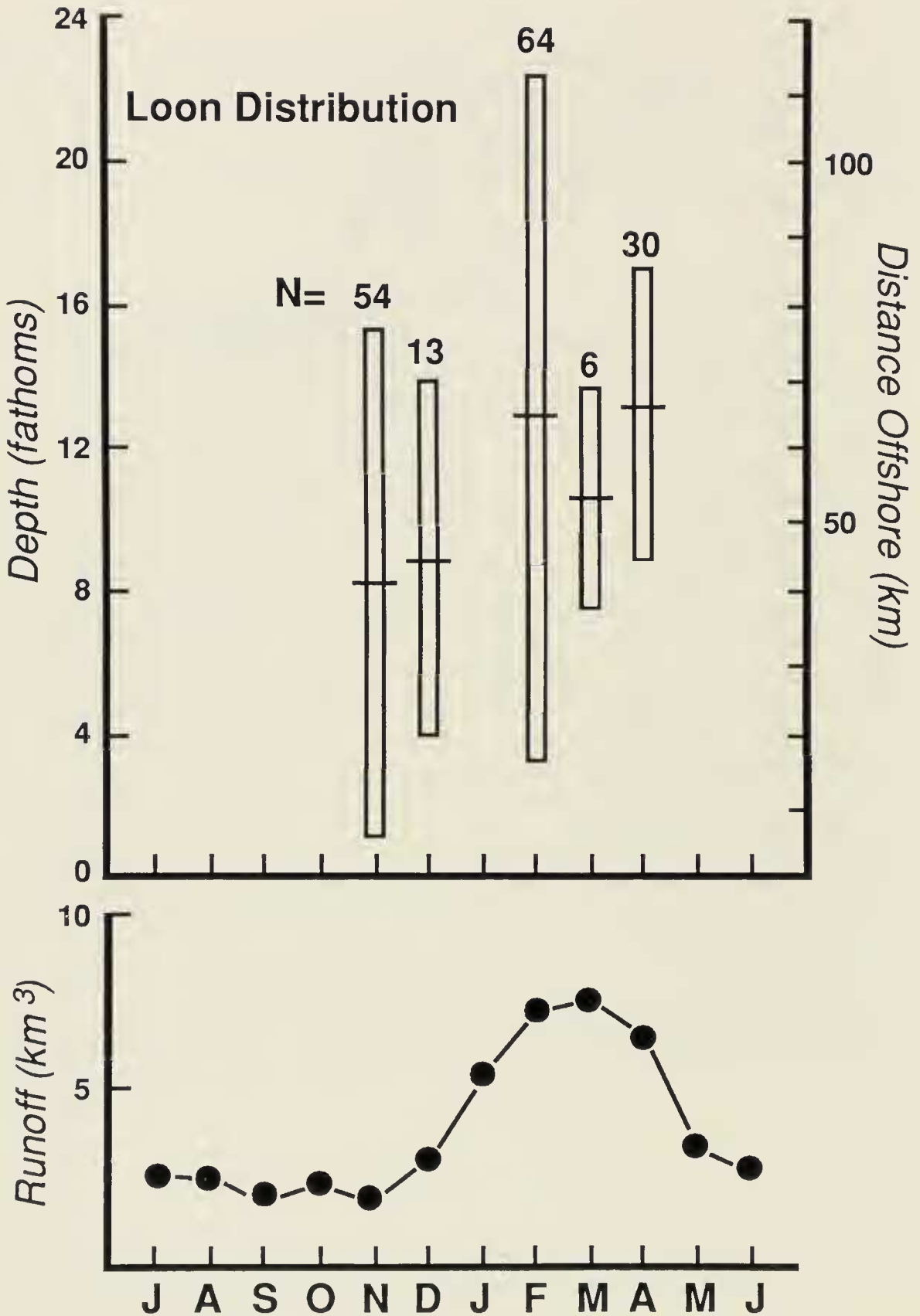


FIG. 2. Seasonal changes in the cross-shelf distribution of Common Loons and their relation to discharge rates of turbid river water. Lines and bars represent mean and SD, respectively; N refers to sample size (number of 15-min, 300 m band transects recording one or more loons).

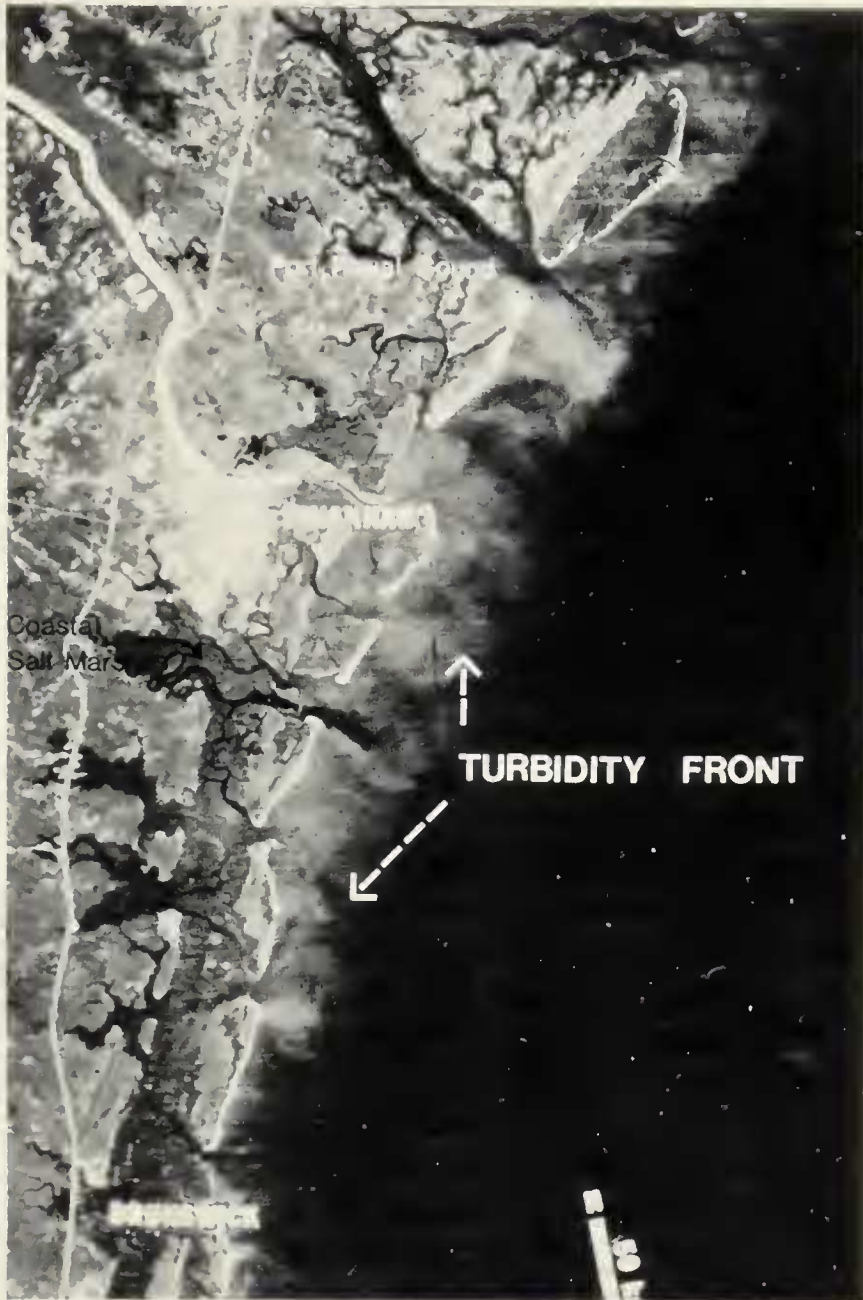


FIG. 3. Infrared image of the Georgia coast taken with thematic mapper aboard Landsat D. The image was taken at 0943 h EST on 9 November 1982 and provided by H. Kim, NASA Goodard Space Flight Center. Note the irregular width and configuration of near shore, turbid waters (light-colored) avoided by wintering Common Loons.

#### DISCUSSION

Methods used to examine habitat use and selection by wintering Common Loons were in large part dictated by the high variance of the at-sea counts. Because many counts recorded no loons, frequency distributions were highly skewed and non-normal. Because the chi-square technique uses zero counts only for calculating expected probabilities, and because

TABLE 3  
POPULATION PARAMETER ESTIMATES OF WINTERING COMMON LOONS LISTED BY HABITAT TYPE

Habitat	0–19 m	20–39 m	40–59 m	60–200 m
Surface area censused (km <sup>2</sup> )	347.8	158.8	39.8	41.0
No. loons	145	16	0	1
Density (km <sup>-2</sup> )	0.42	0.10	0.00	0.02
N (no. counts)	310	140	40	37
$\bar{x}$ density (km <sup>-2</sup> )	0.35	0.08	0.00	0.02
SE	0.05	0.04	0.00	0.02
90% C.I.	0.09	0.06	0.00	0.03

it does not require the assumptions of normality as do parametric tests, its use may be advocated in other studies of marine bird distributions (cf. Schneider and Duffy 1985).

Regular occurrence of Common Loons far out at sea was not expected. Cramp and Simmons (1974) state that loons remain within a few kilometers of shore throughout most of their winter range (see also Clapp et al. 1982). However, early accounts (Bent 1919) referred to loons wintering far offshore, and Lee (1987) recently documented loons in winter using waters 20–500 fathoms (ca 40–1000 m) deep and 32–56 km from land off North Carolina. Loons might be expected farther offshore in the South Atlantic Bight because the shelf is broader and more shallow than on the remainder of the eastern North American coastline. Powers and Cherry (1983) found that the offshore distribution of loons was strongly influenced by configuration of the shelf off the northeastern United States, loons being closest to land where the shelf is narrow and farther from land where the shelf is wide.

Relative abundances of wintering Common Loons were higher in the South Atlantic Bight than reported elsewhere in deep marine waters. The number of loons observed varied from 1.00 to 3.44 individuals h<sup>-1</sup> on the inner and middle shelf compared to 0.34 h<sup>-1</sup> off North Carolina (Lee 1987) and 0.10 to 1.00 h<sup>-1</sup> in the northern Chesapeake Bight (Rowlett 1980). McIntyre (1978) reported that wintering loons in a Virginia bay occupied individual feeding territories of 4–8 ha or 12.5–25 birds km<sup>-2</sup>. This figure is over an order of magnitude higher than densities in the South Atlantic Bight, but shallow and more fertile estuarine habitats may support greater numbers of loons than the deep, relatively impoverished waters of the continental shelf.



Loons on the South Atlantic Bight continental shelf appeared to be limited in both shoreward and seaward directions by the amount of suitable habitat. Loon abundances dropped off sharply where the continental shelf begins to deepen (Fig. 1). This coincides roughly with the maximum diving depths of loons, about 30–40 m (Shoryer 1947). Because loons were observed with benthic fish and crabs in their bills (pers. obs.), deeper water may make some prey inaccessible farther offshore in this region. Lee (1987), however, found a few loons in waters nearly 1000 m deep.

Loons avoided the highly turbid waters near shore (Fig. 3) and moved farther offshore during midwinter (Fig. 2) as turbid water was advected seaward by river discharge. Loons were frequently counted only after ships had crossed turbidity fronts into clearer water. Because loons are diurnal, visually oriented predators, highly turbid water may preclude prey detection. McIntyre and Barr (1983) found a positive correlation between rafting and sunset times, which reinforces the concept that feeding is related to available light levels in the water column. Further studies are needed to determine whether water column turbidity directly influences loon distribution and foraging.

The South Atlantic Bight continental shelf may represent a major wintering ground for Common Loons. On the Atlantic seaboard, few loons winter at sea north of Cape Hatteras (Powers and Cherry 1983). Population estimates of Common Loons from my study ranged from 8700 to 20,000 individuals for the southeastern U.S. continental shelf between 29° and 35°N. Highly turbid water, which loons avoided, is mainly restricted to the central portion of this study area between 30° and 33°N. Because more suitable habitat is present outside the area of high river discharge, these population estimates for the continental shelf tend to be conservative. Numbers of loons may also have been underestimated because of the often obscured viewing conditions at sea or because birds were missed during foraging dives (cf. Tasker et al. 1984).

#### ACKNOWLEDGMENTS

Financial support was generously provided by the North American Loon Fund in 1984 and 1986. Additional funds came from the Univ. of Georgia Dept. of Zoology, Burleigh-Stoddard Fund, Johnson Endowment Fund of the WHOI Marine Policy Center, and NSF grants OCE81-10707 to L. R. Pomeroy and OCE81-17761 to G.-A. Paffenhofer. Logistic support was provided by the University of Georgia Marine Extension Service, Skidaway Institute of Oceanography, South Carolina Wildlife and Marine Resources Department, and the National Oceanic Atmospheric Administration/National Marine Fisheries Service. G. Grossman, D. W. Menzel, G.-A. Paffenhofer, L. R. Pomeroy, M. Rawson, T. E. Targett, G. Ulrich, and H. L. Windom provided access to cruises and equipment. P. Christian, M. Harris, D. Kearns, R. Manns, and P. W. Stangcl assisted in the field. This is WHOI Contribution No. 7215.

## LITERATURE CITED

- ALEXANDER, L. L. 1985. Trouble with loons. *Living Bird Quart.* 3:10-13.
- ALLDREDGE, J. R. AND J. T. RATTI. 1986. Comparison of some statistical techniques for analysis of resource selection. *J. Wildl. Manage.* 50:157-165.
- ALVO, R. 1986. Lost loons of the northern lakes. *Natl. Hist.* 95:58-65.
- ATKINSON, L. P., T. N. LEE, J. O. BLANTON, AND W. S. CHANDLER. 1983. Climatology of the southeastern United States continental shelf waters. *J. Geophys. Res.* 88:4705-4718.
- BENT, A. C. 1919. Life histories of North American diving birds. *Bull. U.S. Natl. Mus.* No. 107:47-62.
- BHATTACHARYYA, G. K. AND R. A. JOHNSON. 1977. *Statistical concepts and methods.* John Wiley & Sons, New York, New York.
- BOWMAN, M. J. AND W. E. ESAAS. 1978. *Oceanic fronts in coastal processes.* Springer-Verlag, New York, New York.
- BYERS, C. R., R. K. STEINHORST, AND P. R. KRAUSMAN. 1984. Clarification of a technique for analysis of utilization-availability data. *J. Wildl. Manage.* 48:1050-1053.
- CLAPP, R. B., R. C. BANKS, D. MORGAN-JACOBS, AND W. A. HOFFMAN. 1982. Marine birds of the southeastern United States and Gulf of Mexico. Part I. Gaviiformes through Pelecaniformes. U.S. Fish Wildl. Serv., Office Biol. Serv., Washington, D.C. FWS/OBS-82/01.
- CRAMP, S. AND K. E. L. SIMMONS (eds.). 1974. *Handbook of the birds of Europe, the Middle East and North Africa: the birds of the western Palearctic.* Vol. 1. Ostrich to Ducks. Oxford Univ. Press, Oxford, England.
- DAUB, B. C. 1989. Behavior of Common Loons (*Gavia immer*) in winter. *J. Field Ornithol.* 60:305-311.
- DIXON, W. J. AND F. J. MASSEY. 1969. *Introduction to statistical analysis.* McGraw-Hill, New York, New York.
- HANEY, J. C. 1986. Pelagic seabird ecology and its relationship to environmental heterogeneity in the South Atlantic Bight. Ph.D. diss., Univ. Georgia, Athens, Georgia.
- HASELTINE, S. D., J. S. FAIR, S. A. SUTCLIFFE, AND D. M. SWINEFORD. 1983. Trends in organochlorine and mercury residues in Common Loon (*Gavia immer*) eggs from New Hampshire. *Trans. Northeast. Sect. Wildl. Soc.* 40:131-141.
- HEINEMANN, D. 1981. A rangefinder for pelagic bird censusing. *J. Wildl. Manage.* 45:489-493.
- JAMES, F. C. AND C. E. MCCULLOCH. 1985. Data analysis and the design of experiments in ornithology. Pp. 1-63 in *Current ornithology* (F. Johnston, ed.). Plenum Press, New York, New York.
- LEE, D. S. 1987. Common Loons wintering in offshore waters. *Chat* 51:40-42.
- MCINTYRE, J. W. 1978. Wintering behavior of Common Loons. *Auk* 95:396-403.
- . 1986. Common Loon. Pp. 678-695 in *Audubon Wildlife Report 1986* (R. L. Disilvestron, ed.). Natl. Aud. Soc., New York, New York.
- AND J. F. BARR. 1983. Pre-migratory behavior of Common Loons on the autumn staging grounds. *Wilson Bull.* 95:121-125.
- NEU, C. W., C. R. BYERS, AND J. M. PEEK. 1974. A technique for analysis of utilization-availability data. *J. Wildl. Manage.* 38:541-545.
- POWERS, K. D. AND J. CHERRY. 1983. Loon migrations off the coast of the northeastern United States. *Wilson Bull.* 95:125-132.
- REAM, C. H. 1976. Loon productivity, human disturbance, and pesticide residues in northern Minnesota. *Wilson Bull.* 88:427-432.

- ROWLETT, R. A. 1980. Observations of marine birds and mammals in the northern Chesapeake Bight. U.S. Fish Wildl. Serv., Office Biol. Serv., Washington, D.C. FWS/OBS-80/04.
- SCHNEIDER, D. C. AND D. C. DUFFY. 1985. Scale-dependent variability in seabird abundance. *Mar. Ecol. Progr. Ser.* 25:211-218.
- SHORYER, A. W. 1947. The deep diving of the loon and Oldsquaw and its mechanism. *Wilson Bull.* 59:151-159.
- TASKER, M. L., P. H. JONES, T. DIXON, AND B. F. BLAKE. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. *Auk* 101:567-577.
- TITUS, J. R. AND L. W. VAN DRUFF. 1981. Responses of the Common Loon to recreational pressure in the Boundary Waters Canoe Area, northeastern Minnesota. *Wildl. Monogr.* 79.